CLAIMS

What is claimed is:

1. A method of perforating a subterranean formation which is penetrated by a wellbore, the wellbore having casing cemented therein, a cement sheath around the casing, so as to establish fluid communication between the formation and the wellbore, the method comprising the steps of:

perforating the casing using a mechanical perforator; and thereafter

igniting a propellant material disposed in the perforated casing thereby perforating the cement sheath.

2. A method as in 1 further comprising the step of stimulating the formation with an acid stimulator.

3. A method as in 1 wherein the step of perforating the casing using a mechanical perforator further includes perforating at least some distance into the cement sheath.

4. A method as in 1 wherein the mechanical perforator comprises at least one toothed wheel.

5. A method as in 4 wherein the at least one toothed wheel included extendable teeth.

6. A method as in 1 wherein the mechanical perforator comprises needle-punch perforator.

7. A method as in 1 wherein the propellant material comprises a propellant stick.

8. A method as in 1 wherein the propellant material comprises a propellant sleeve.

9. A method as in 1 wherein the step of igniting the propellant material further comprises expelling an abrasive material through the perforations in the casing thereby scouring the perforations in the cement sheath.

10. A method as in 1 wherein the propellant further acts in part to perforate the formation.

11. A method as in 9 wherein the abrasive material acts in part to perforate the formation.

12. A method as in 1 further comprising the step of deploying in the casing a perforator subassembly including the mechanical perforator.

13. A method as in 12 wherein the mechanical perforator includes at least one toothed wheel.

14. A method as in 1 further comprising the step of deploying in the casing a propellant subassembly including the propellant material.

15. A method as in 14 wherein the propellant subassembly further comprises an abrasive material.

16. A method as in 15 wherein the step of igniting the propellant material further comprises expelling the abrasive material through the perforations in the casing.

17. A method as in 2 further comprising the step of deploying in the casing an acid stimulation subassembly for delivery of the acid stimulator to the formation.

18. A method as in 1 wherein the casing is expandable casing.

19. An apparatus for perforating a subterranean formation which is penetrated by a wellbore, so as to establish fluid communication between the formation and the wellbore, the wellbore having casing cemented therein, a cement sheath around the casing, the apparatus comprising:

a mechanical perforator subassembly for creating perforations at least in the casing; and

a propellant subassembly for creating perforations in at least the cement sheath.

20. An apparatus as in 19 further comprising an acid stimulation subassembly for delivery of the acid stimulator to the formation.

21. An apparatus as in 19 wherein the mechanical perforator capable of perforating at least some distance into the cement sheath.

22. An apparatus as in 19 wherein the mechanical perforator subassembly comprises at least one toothed wheel.

23. An apparatus as in 22 wherein the at least one toothed wheel includes extendable teeth.

24. An apparatus as in 19 wherein the mechanical perforator subassembly comprises a needle-punch perforator.

25. An apparatus as in 19 wherein the propellant subassembly comprises a propellant stick.

26. An apparatus as in 19 wherein the propellant subassembly comprises a propellant sleeve.

27. An apparatus as in 19 wherein the propellant subassembly comprises propellant and an abrasive material for expulsion through the perforations in the casing created by the mechanical perforation assembly.

28. An apparatus as in 19 wherein the propellant subassembly is further capable of creating perforations in the formation.

29. An apparatus as in 27 wherein the abrasive material is capable of perforating the formation.

30. An apparatus as in 19 wherein the casing is expandable casing.

31. A method of perforating a subterranean formation which is penetrated by a wellbore, so as to establish fluid communication between the formation and the wellbore, the method comprising the steps of:

cementing casing in the wellbore thereby creating a cement sheath around at least a portion of the casings

perforating the casing using a mechanical perforator; and thereafter

igniting a propellant material disposed in the perforated casing.

32. A method as in 31 wherein the step of cementing casing further comprises expanding the casing.

33. A method as in 31 further comprising the step of stimulating the formation with an acid stimulator.

34. Method as in 31 wherein the step of perforating the casing using a mechanical perforator further includes perforating at least some distance into the cement sheath.

35. A method as in 31 wherein the mechanical perforator comprises at least one toothed wheel.

36. A method as in 31 wherein the mechanical perforator comprises a needle-punch perforator.

37. A method as in 31 wherein the propellant material comprises a propellant sleeve.

38. A method as in 31 wherein the step of igniting the propellant material further comprises expelling an abrasive material through the perforations in the casing.

39. A method as in 32 further comprising the step of stimulating the formation with an acid stimulator.

40. A method as in 32 wherein the step of perforating the casing using a mechanical perforator includes perforating at least some distance into the cement sheath.

41. A casing perforator apparatus for perforating casing disposed in a wellbore, the apparatus comprising:

a perforator body; and

a plurality of toothed wheels movably mounted to the perforator body.

42. An apparatus as in 41 the casing perforator having three toothed wheels, each wheel having a different axis of rotation.

43. An apparatus as in 41 wherein at least one of the toothed wheels has extendable teeth.

44. An apparatus as in 41 further comprising means for moving the toothed wheels into contact with the casing.

45. An apparatus as in 41 wherein the casing is cemented in the wellbore, having a cement sheath around the casing.

46. An apparatus as in 45 wherein the plurality of toothed wheels have teeth capable of perforating at least some distance into the cement sheath.

47. A casing perforator apparatus for perforating casing disposed in a wellbore, the apparatus comprising:

a perforator body;

and at least one toothed wheel movably mounted to the body, each wheel having a plurality of extendable teeth movable between a retracted position and an extended position.

48. An apparatus as in 47 the at least one toothed wheel comprising three toothed wheels.

49. An apparatus as in 47, each toothed wheel having an actuator for moving the teeth to the extended position.

50. An apparatus as in 49, each toothed wheel having a locking mechanism for at least temporarily locking the teeth in the extended position…

51. A casing perforator apparatus for perforating casing disposed in a wellbore, the apparatus comprising:

a perforator body; and

a plurality of perforator needles movable between a retracted position and an extended position; and

an actuating means for moving the needles from the retracted position to the extended position.

52. An apparatus as in 51 the actuating means capable of moving the needles from the extended position to the retracted position.

53. An apparatus as in 51 wherein the needles are shearable from the perforator body.

54. An apparatus as in 51 wherein the needles are mounted in a generally radial position when in the retracted position.

55. An apparatus as in 53 wherein the needles are soluble in acid solution.

56. An apparatus as in 51 wherein the actuating means is a substantially conical expansion plug

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57. An apparatus as in 51 wherein the casing is cemented in the wellbore a cement sheath around the casing.

58. An apparatus as in 57 wherein the needles are capable of perforating through the casing and at least some distance into the cement sheath.

59. A method of perforating a casing in a wellbore, the method comprising:

positioning a perforator in the casing, the perforator having a plurality of perforator needles movable mounted thereon, the needles in a retracted position; and

moving the needles to an extended position and perforating the casing with the needles.

60. A method as in 59 further comprising the step of moving the needles from the extended position to the retracted position.

61. A method as in 59 further comprising the steps of disconnecting the needles from the perforator.

62. A method as in 61 further comprising dissolving the needles.

63. A method as in 59 wherein the step of moving the needles includes moving an extension plug through the perforator.

64. A method as in 59 wherein the casing is cemented in the wellbore, a cement sheath around the casing, and further comprising the step of perforating at least some distance into the cement sheath.

65. A well casing apparatus for a subterranean formation which is penetrated by a wellbore, the casing comprising:

a substantially tubular casing having a casing wall with a plurality of perforations therethrough; and

a plurality of sacrificial plugs secured to the casing wall and sealing the plurality of perforations.

66. An apparatus as in 65 wherein the casing and plugs are expandable, such that the plugs remain secured to the casing wall, sealing the plurality of perforations, when the casing is expanded.

67. An apparatus as in 65 wherein the sacrificial plugs are soluble in an acid or caustic solution.

68. An apparatus as in 67 wherein the plugs comprise aluminum.

69. An apparatus as in 66 wherein the sacrificial plugs are soluble in an acid or caustic solution.

70. An apparatus as in 69 wherein the plugs comprise aluminum.

71. An apparatus as in 66 wherein the sacrificial plugs are shearable.

72. An apparatus as in 71, the casing wall enclosing a casing bore, and wherein each plug has a body portion engaging the casing wall and having a stub portion protecting into the casing bore, the body portion intersected by a relief pocket.

73. As in 65 wherein the sacrificial plugs further comprise a wellbore protrusion projecting into the wellbore.

74. An apparatus as in 66 wherein the sacrificial plugs further comprise a wellbore protrusion projecting into the wellbore.

75. An apparatus as in 74 wherein the plug protrusions comprise EPDM.

76. An apparatus as in 65 wherein the sacrificial plugs comprise reactive plugs.

77. An apparatus as in 14 wherein the reactive plugs are mounted to the casing wall in preformed recesses therein.

78. An apparatus as in 76 wherein the reactive plugs comprise an elastomer.

79. An apparatus as in 81 wherein the reactive plugs expand in a prescribed geometric pattern in the presence of a pre-selected additive.

80. An apparatus as in 79 wherein the reactive plugs expand in the presence of diesel.

81. An apparatus as in 66 wherein the sacrificial plugs comprise reactive plugs.

82. An apparatus as in 81 wherein the reactive plugs are mounted to the casing wall in preformed recesses.

83. An apparatus as in 81 wherein the reactive plugs are mounted to the casing wall in preformed recesses.

84. An apparatus as in 81 wherein the reactive plugs expand in a prescribed geometric pattern in the presence of a pre-selected additive.

85. An apparatus as in 84 wherein the reactive plugs expand in the presence of diesel.

86. An apparatus as in 76 wherein the reactive plugs dissolve in an acid or caustic solution.

87. An apparatus as in 81 wherein the reactive plugs dissolve in an acid or caustic solution.

88. A method of completing a well having a wellbore penetrating a subterranean formation, the method comprising the steps of:

placing a substantially tubular casing having a casing wall enclosing a casing bore, the casing wall having a plurality of sacrificial plugs secured to the casing wall and sealing the plurality of perforations; and

rupturing the sacrificial plugs, thereby establishing fluid communication between the wellbore and the casing bore.

89. A method as in 88 further comprising the step of expanding the casing and sacrificial plugs such that the plugs remain secured to the casing wall and sealing the plurality of perforations during expansion of the casing and plugs.

90. A method as in 89 further comprising the step of cementing the casing in the wellbore.

91. A method as in 88 wherein the step of rupturing the plugs further comprises dissolving the plugs.

92. A method as in 91 wherein the plugs are dissolved in an acid solution.

93. A method as in 91 wherein the plugs comprise aluminum.

94. A method as in 89 wherein the step of rupturing the plugs further comprises dissolving the plugs.

95. A method as in 89 wherein the step of rupturing the plugs comprises shearing a portion of the plugs.

96. A method as in 95 wherein the plugs each comprise a body portion secured to the casing wall and stab portion projecting in to the casing bore, the body portion intersected by a relief pocket.

97. A method as in 95 wherein the plugs each comprise a protrusion extending into the wellbore.

98. A method as in 90 the step of cementing creating a cemented sheath around the casing, and wherein the plugs comprise protrusions projecting into the wellbore and into the cement sheath.

99. A method as in 90 wherein the plugs are reactive plugs and further comprising the step of expanding the reactive plugs such that a protruding portion of each of the plugs projects into the wellbore and into the cement.

100. A method as in 99 wherein the reactive plugs expand in the presence of a preselected additive.

101. A method as in 100 wherein the step of cementing further comprises the step of placing the additive into the wellbore adjacent the plugs in the casing.

102. A method as in 101 wherein the reactive plugs are an elastomer and the additive is diesel.

103. A method as in 99 further comprising the step of dissolving the reactive plugs after the step of expanding the reactive plugs.

104. A method as in 88 further comprising the step of cementing the casing in the wellbore.

105. A method as in 104 wherein the plugs are reactive plugs and further comprising the step of expanding the reactive plugs such that a protruding portion of each of the plugs projects into the wellbore and into the cement.

106. A method as in 105 wherein the reactive plugs expand in the presence of a preselected additive.

107. A method as in 105 wherein the step of cementing further comprises the step of placing the additive into the wellbore adjacent the plugs in the casing.

108. A method as in 107 wherein the reactive plugs are an elastomer and the additive is diesel.

109. A method as in 105 wherein the plugs are reactive plugs and further comprising the step of expanding the reactive plugs such that a protruding portion of each of the plugs projects into the wellbore and into the cement.

110. An apparatus for completing a well in a subterranean formation penetrated by a wellbore, the apparatus comprising:

a casing having a casing wall;

a plurality of perforations through the casing wall;

a plurality of plugs corresponding to the plurality of perforations, the plugs sealing the plurality of perforations; and

a plurality of extendable fingers secured to the casing wall adjacent the plurality of the perforations, each of the fingers movable between a run-in position wherein the fingers do not interfere with the casing being run-in to the wellbore, and an extended position wherein the fingers project radially from the casing wall.

111. An apparatus as in 110 wherein the casing is expandable.

112. An apparatus as in 111 wherein each of the fingers is movable between the extended position and a final position wherein each finger pierces a corresponding plug.

113. An apparatus as in 111 wherein each finger comprises an explosive charge for perforating the subterranean formation.

114. An apparatus as in 110, the casing wall enclosing a casing bore, and further comprising a propellant subassembly in the casing bore ignitable to vacate the casing bore through the plurality of perforations.

115. The apparatus as in 110, wherein each finger is pivotally attached to the casing wall.

116. The apparatus as in 110, wherein a wire extends from each finger, the wire for engaging the wellbore and moving the finger between the run-in and the extended positions.

117. The apparatus as in 110, the fingers movable between the run-in and extended positions by a spring device.

118. The apparatus as in 117, wherein the spring device is a torsion spring device.

119. A method of perforating a subterranean formation which is penetrated by a wellbore, so as to establish fluid communication between the formation and the wellbore, the method comprising the steps of:

running a casing into the wellbore, the casing having a casing wall, a plurality of perforations through the casing wall, a plurality of plugs sealing the plurality of perforations, and a plurality of fingers secured to the casing wall adjacent the plurality of perforations, the fingers in a run-in position wherein the fingers do not interfere with running the casing into the wellbore;

moving each of the plurality of fingers to an extended position wherein each finger projects radially outward from the casing wall; and thereafter

igniting a propellant, the propellant exiting through the plurality of perforations and the plurality of fingers thereby perforating the formation.

120. A method as in 119 further comprising the step of expanding the casing.

121. method as in 119wherein the propellant is mounted in the plurality of fingers.

122. A method as in 119 wherein the propellant is disposed in the casing.

123. A method as in 122 further comprising the step of running a propellant subassembly into the casing.

124. A method as in 119 further comprising the step of cementing the casing in the wellbore.

125. A method as in 124 further comprising the steps of expanding the casing.

126. A method as in 119 further comprising the step of moving each of the plurality of fingers from the extended position to a final position wherein each of the fingers pierces a corresponding plug.

127. A method as in 126, the step of moving the fingers to a final position further comprising expanding the casing such that the fingers contact the wellbore wall.

128. A method as in 119 wherein each finger is pivotally attached to the casing wall.

129. A method as in 119 wherein a wire extends from each finger, the wire for engaging the wellbore and moving the finger between the run-in and the extended positions.

130. A method as in 119 the fingers movable between the run-in and extended positions by a spring device.

131. A method as in 130 wherein the spring device is a torsion spring device.